

GEANT4, NA49, and NA61 Jazz (aka Geant4 Modeling of p+C Interactions and Benchmarking vs NA61 and NA49 data)

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NuMI-X meeting
7/11/2013



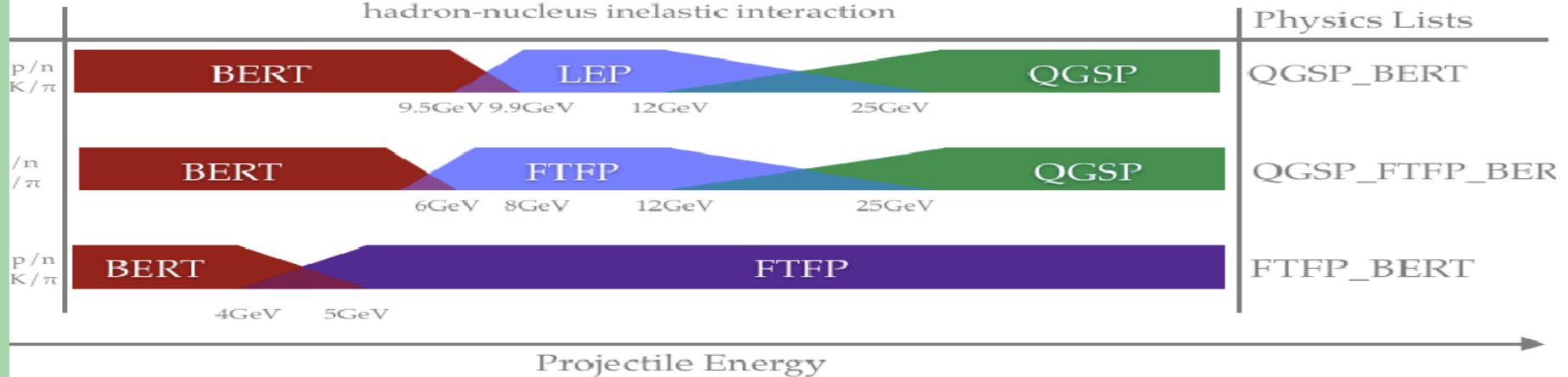


Hadronic Physics in Geant4 - General Remarks

- There is NO “unified” hadronic model
- Hadronic models are valid (or better fit) for combinations
particle type - energy (- target material)
- Need to choose a set of hadronic models to cover all
possible interactions - Physics List (what a user sees)
- The choice is **NOT** a “black box” but depends on use-case:
 - The particles in simulation
 - The energy scale
 - The compromise between accuracy and CPU
- Collection of ready-to-use physics lists exists
- Users can also tailor any of those, or write their own

Geant4 Physics List Composition - Overlap of Models

Simplified schema of model selection for
hadron-nucleus inelastic interaction



NuMI-X: 1st interaction is done by a single model,
hence the focus on the HE models in this talk

Further interactions: a mix of everything...

High Energy Hadronic Physics Models in Geant4

- FTF String model: 3GeV - 100TeV
 - Intense development over the past 4-5 years
 - Smooth interface w/Bertini model at intermediate energies
- QGS String model: 15GeV - 100TeV
 - Somewhat “orphan” in the past several year but...
- Each one serves as basis to “HE generator”:
 - String model itself (gives name to phys.list)
 - String Fragmentation - G4Lund w/FTF, “old” w/QGS; interchangeable
 - Quasi-elastic channel (internal in FTF, CHIPS-like for QGS)
 - (Typically) Precompound at the back end
- Each one has room for improvement

Experimental Datasets for Benchmarking

- **NA61: 31 GeV p on C; NA49: 158 GeV/c p on C**
 - N.Abgrall et al., Phys.Rev. C84, 034604 (2011) (NA61)
 - Communications with NA61 (proton data)
 - <http://spshadrons.web.cern.ch/spshadrons/> (NA49)
- **NOTE: Only a portion of datasets incorporated in our G4 tests so far; more will be added shortly**
- **Additional useful materials:**
 - talk by L.Zambelli of NA61, at G4/HAD meeting (11/28/12)
 - <https://indico.cern.ch/getFile.py/access?contribId=1&resId=0&materialId=slides&confId=218658>
 - includes comparison vs FLUKA
 - constraints: based on G4.9.5 series

Technical Remarks

- Results from Geant4.9.6.p01 (should be the same with Geant4.9.6.p02 which is the recommended version)
- Results obtained at the “process level”, i.e. from modeling a single interaction
- Same (statistically) as the 1st “ProtonInelastic” interaction (for example, stepping action looks at secondaries at the point where the primary track loses its identity)
- Tests include standard FTFP and QGSP configurations, as in pre-fabricated physics lists...
- ... and a custom QGSP+G4LundStringFragmentation combo (not yet available in standard Physics Lists)

!

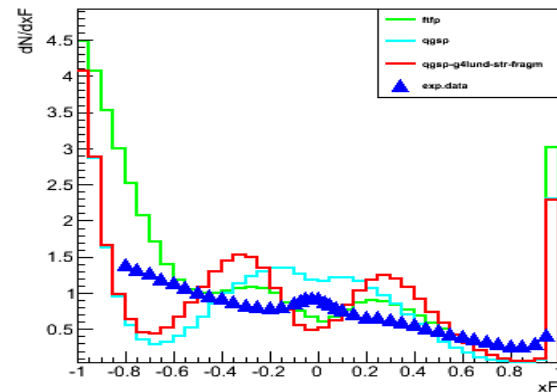


Technical Remarks (cont.)

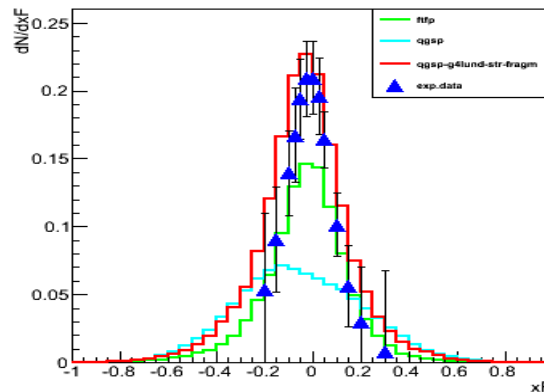
- NOTE-1: quasi-elastic channel is included in the bulk
- NOTE-2 (inspired by Mike K.'s talk on 6/20): our tests may need refinement as it does NOT account for the fact that secondary eta, eta-prime, etc., also decay into pions !

NA49: 158GeV/c proton on C \longrightarrow p, pbar, n, pi⁺, pi⁻

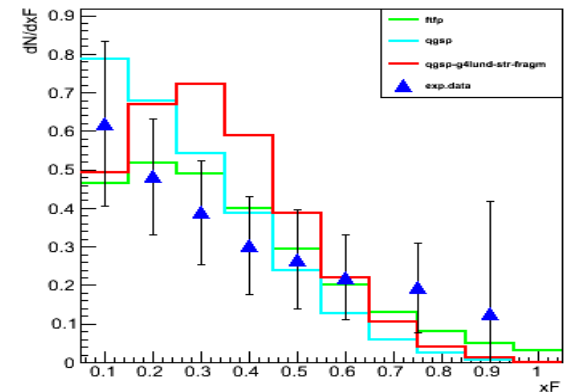
proton + C \rightarrow X + proton



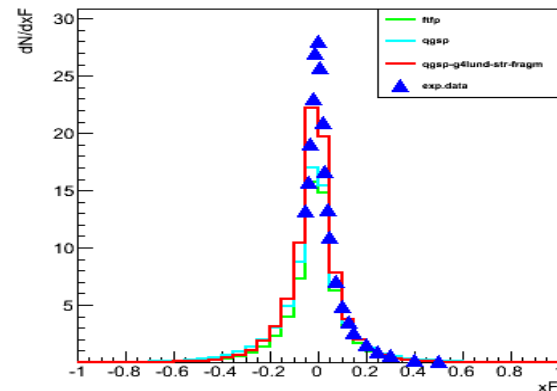
proton + C \rightarrow X + antiproton



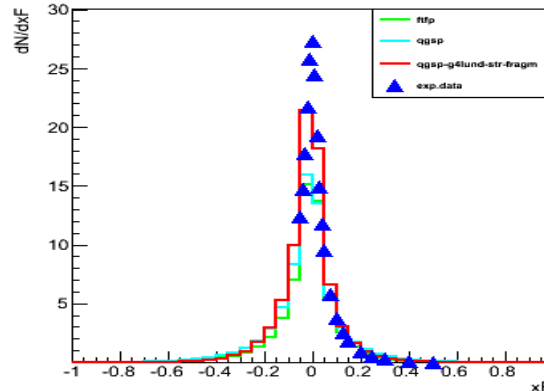
proton + C \rightarrow X + neutron



proton + C \rightarrow X + pi⁺



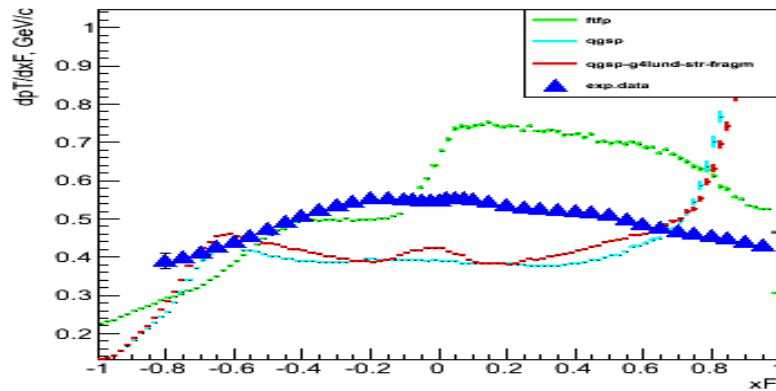
proton + C \rightarrow X + pi⁻



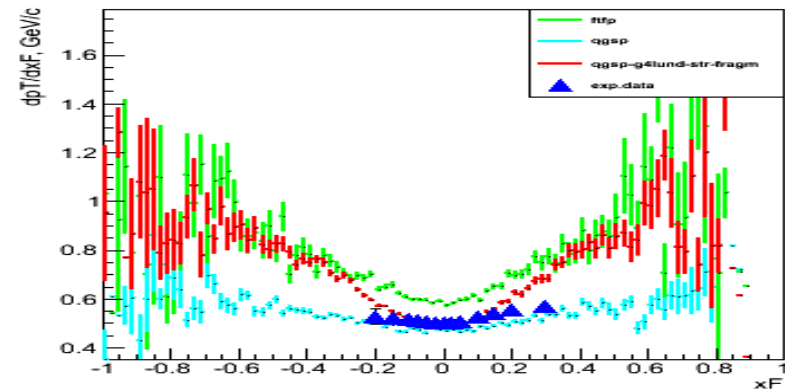
In these plots and onwards:
 Green = standard FTFP
 Light Blue = standard QGSP
 Red = QGSP
 +G4LundStringFragmentation

NA49(cont.): 158GeV/c proton on C \longrightarrow p, pbar, π^+ , π^-

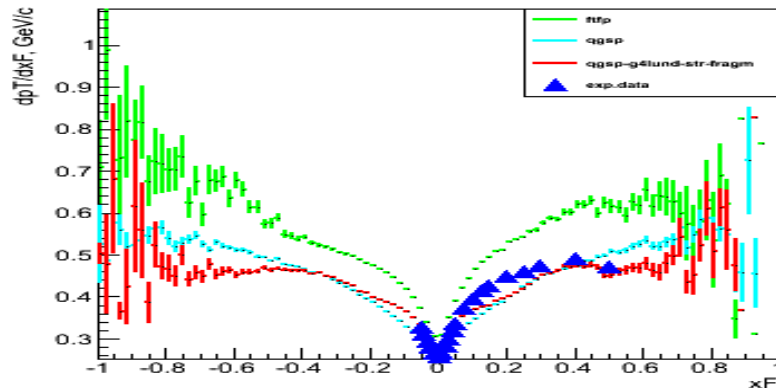
proton + C \rightarrow X + proton



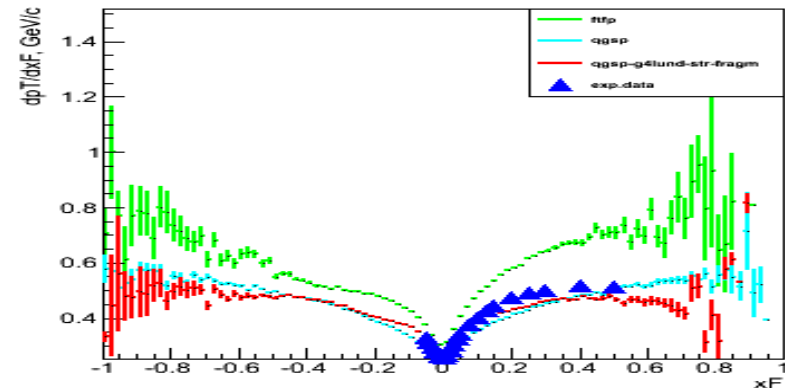
proton + C \rightarrow X + antiproton



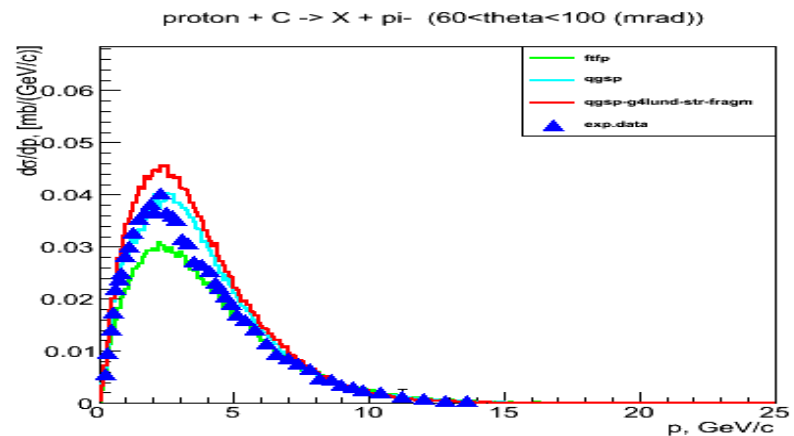
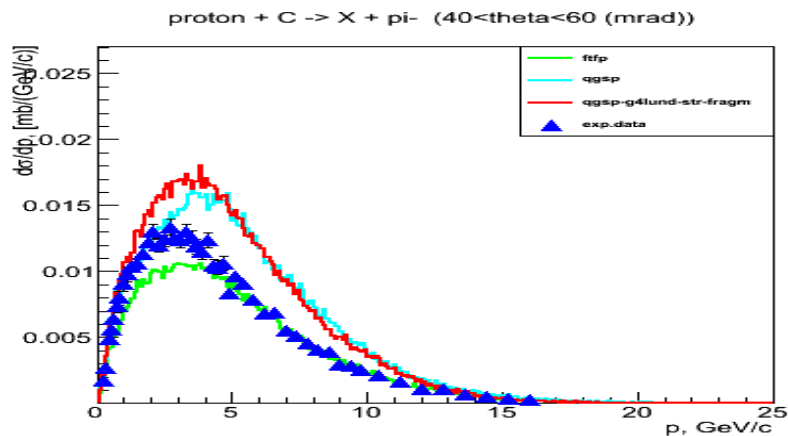
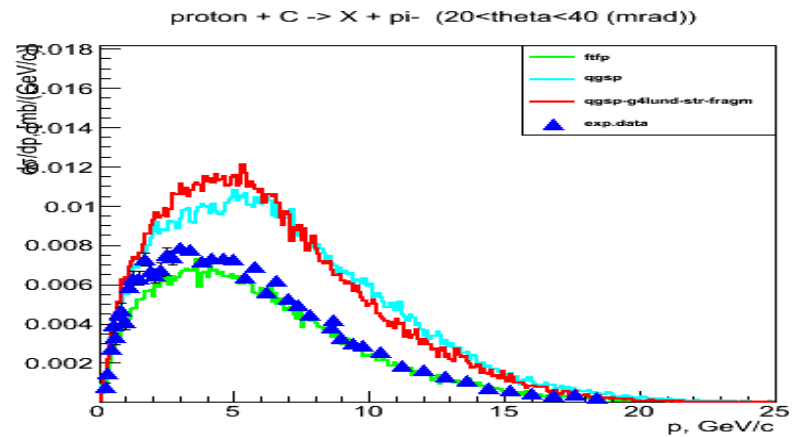
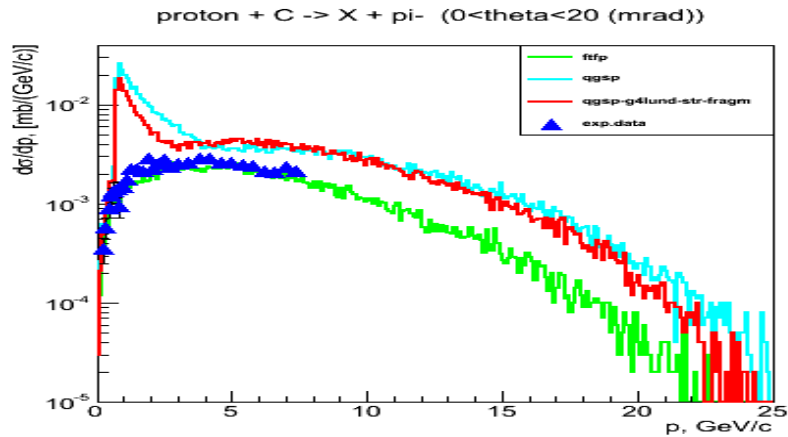
proton + C \rightarrow X + π^+



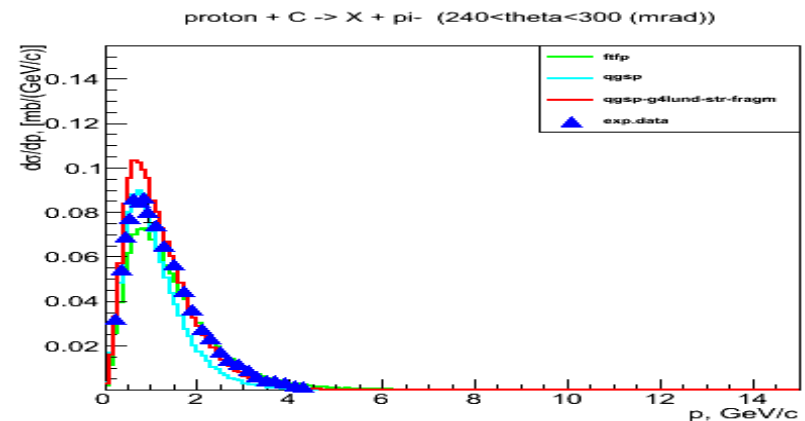
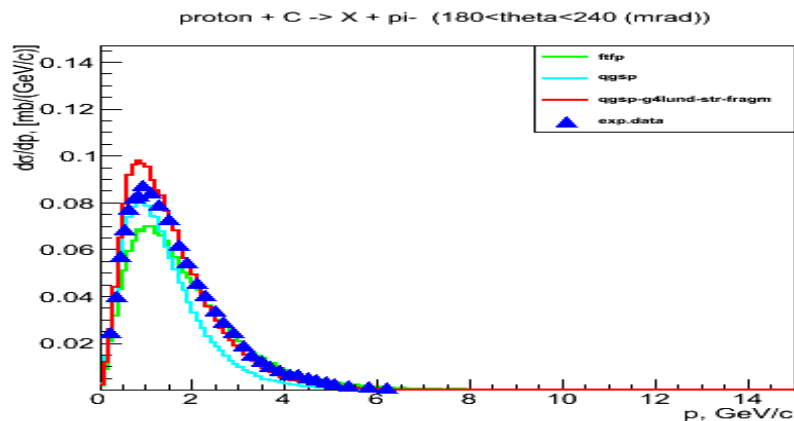
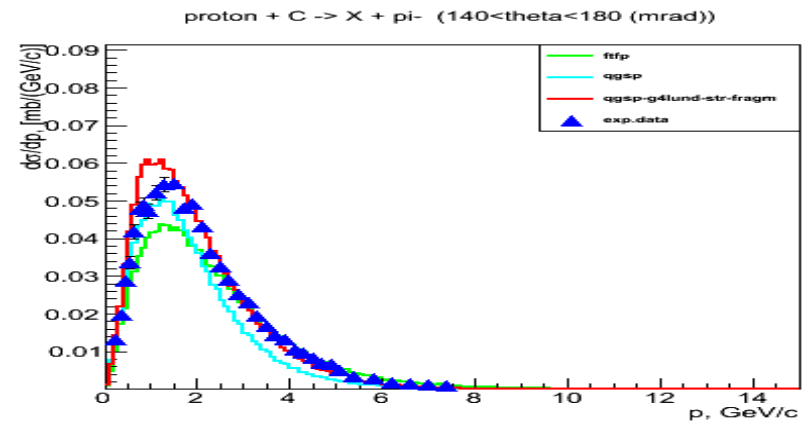
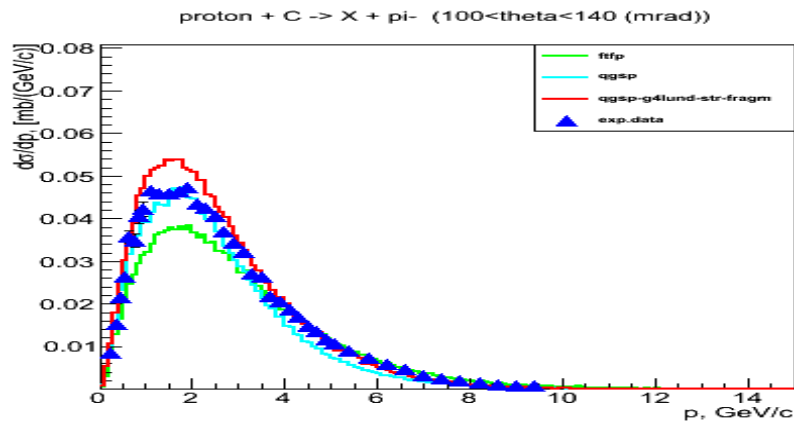
proton + C \rightarrow X + π^-



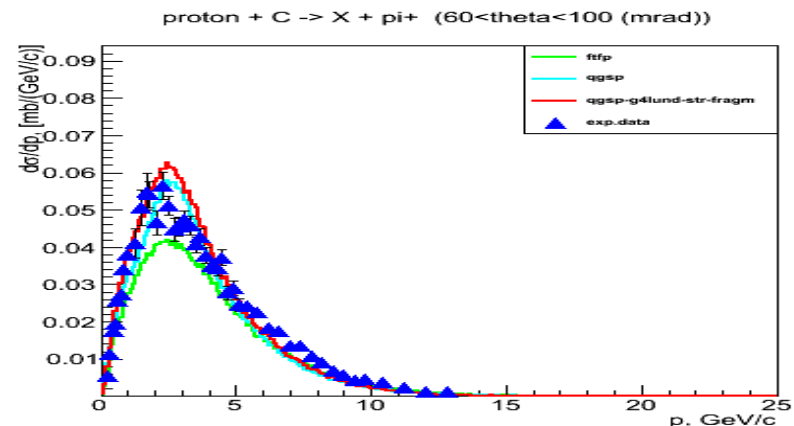
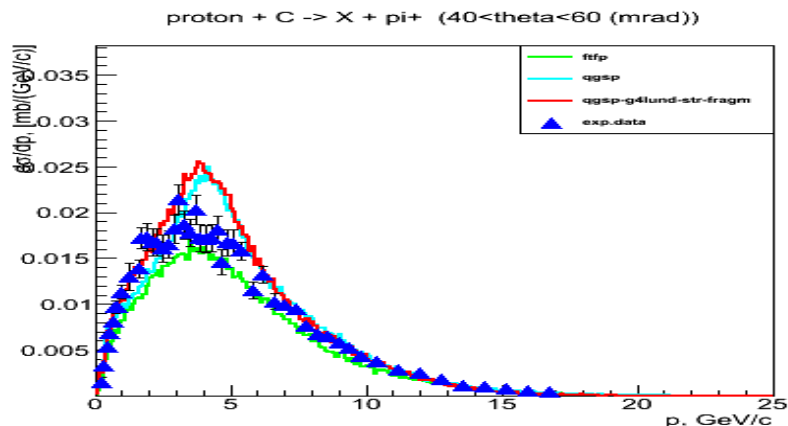
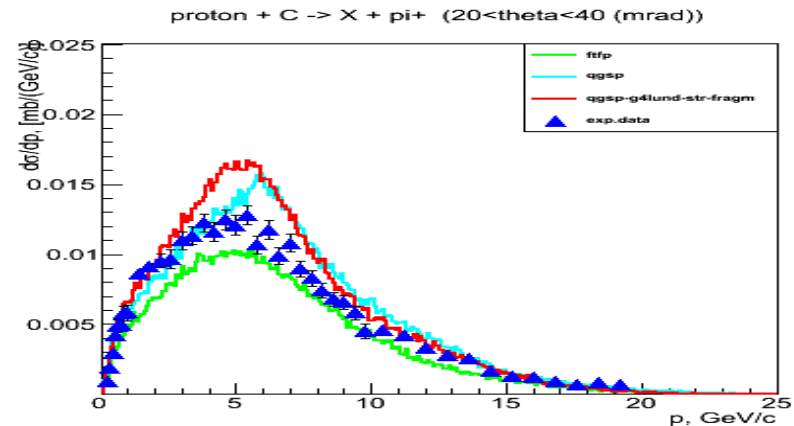
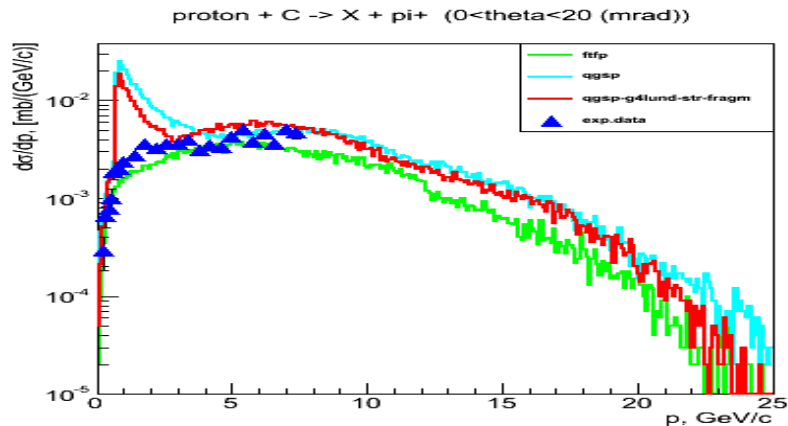
NA61: 31 GeV/c proton on C \longrightarrow π^- + X ($\theta < 100$ mrad)



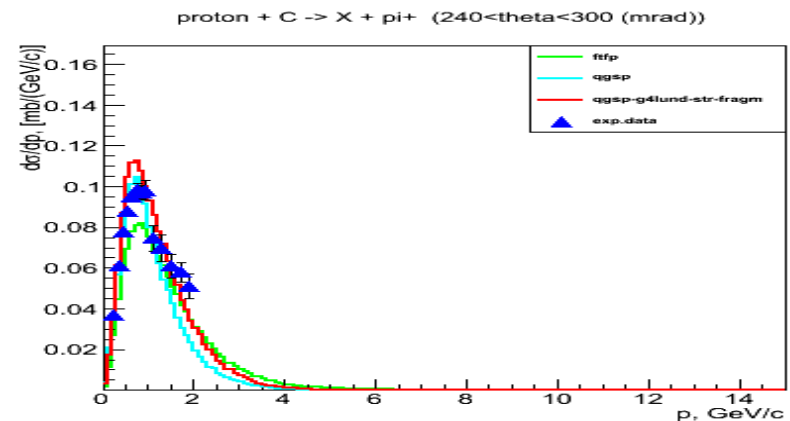
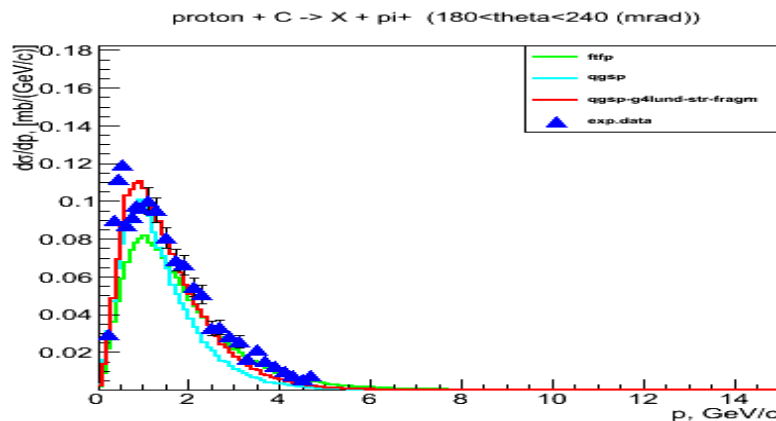
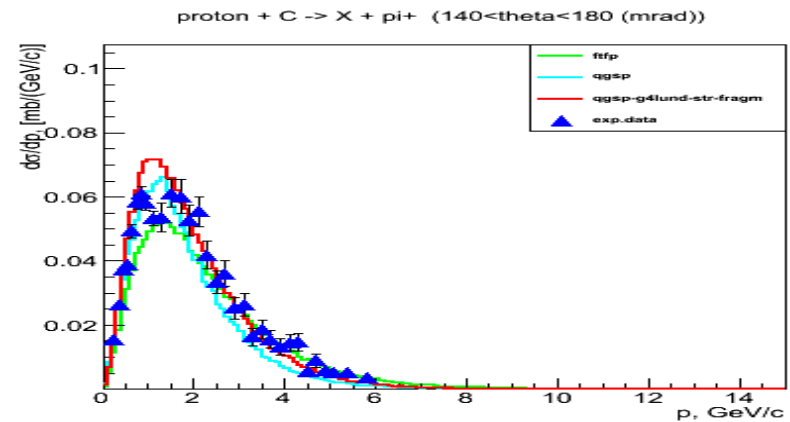
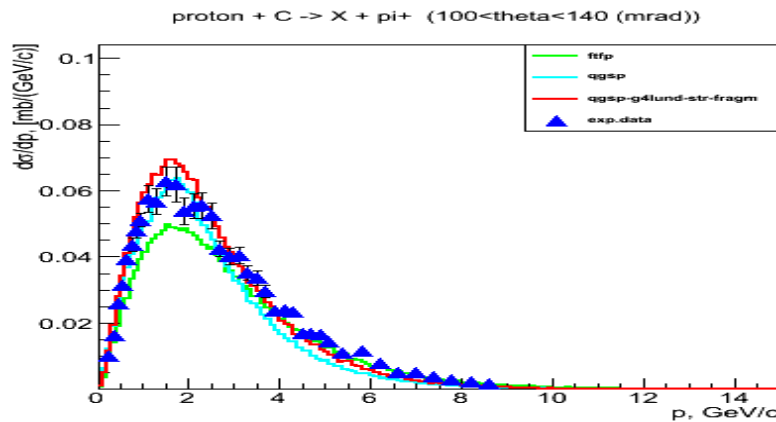
NA61: 31 GeV/c proton on C \longrightarrow π^- + X ($100\text{mrad} < \theta < 300\text{mrad}$)



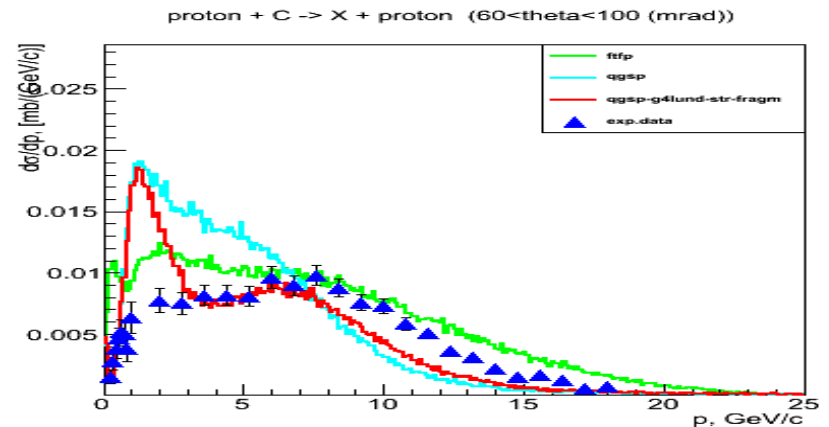
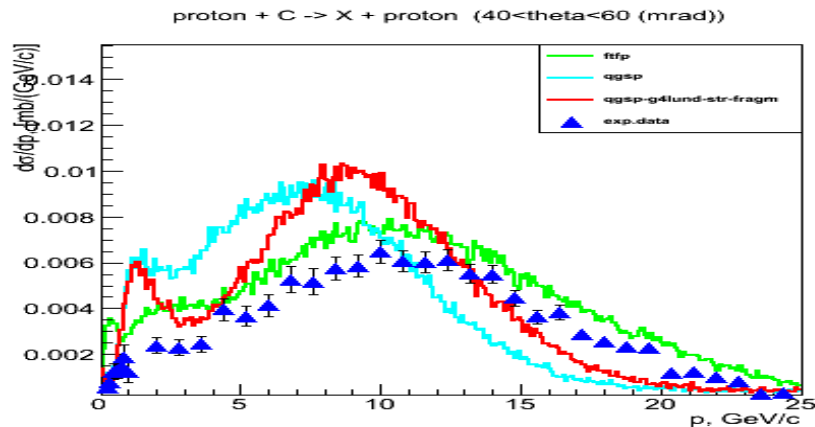
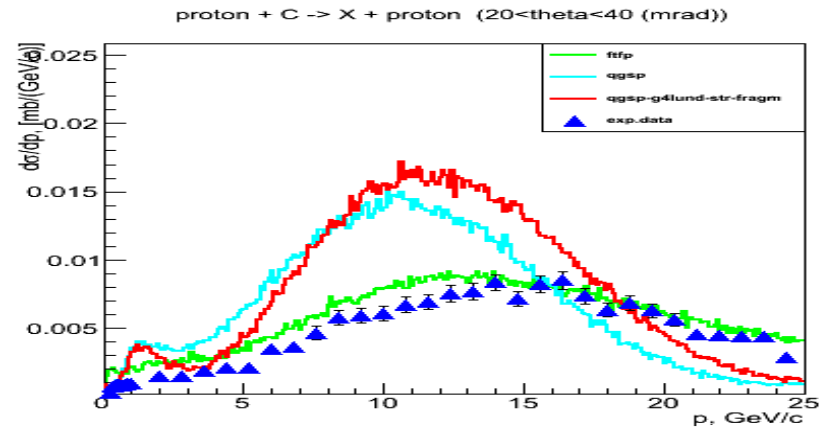
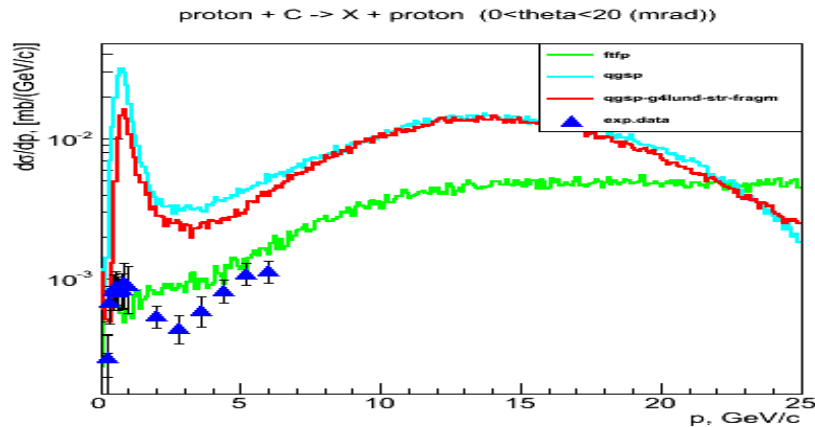
NA61: 31 GeV/c proton on C \longrightarrow π^+ + X ($\theta < 100$ mrad)



NA61: 31GeV/c proton on C \longrightarrow π^+ + X (100mrad < θ < 300mrad)

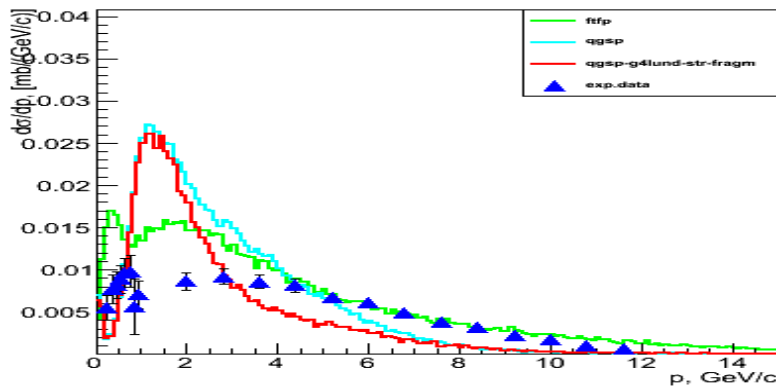


NA61: 31 GeV/c proton on C \longrightarrow p + X ($\theta < 100$ mrad)

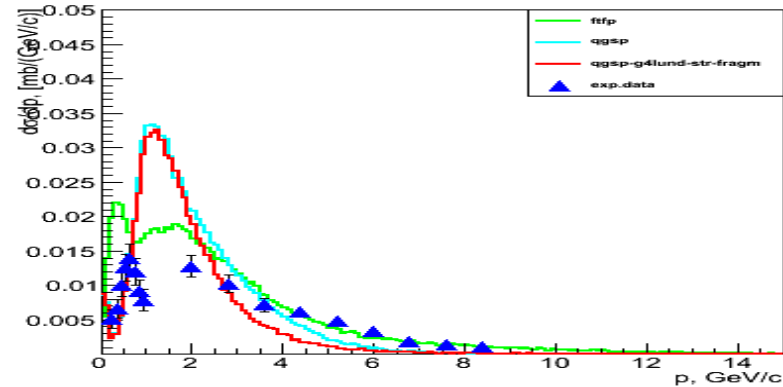


NA61: 31 GeV/c proton on C \longrightarrow p + X (100 mrad < theta < 300 mrad)

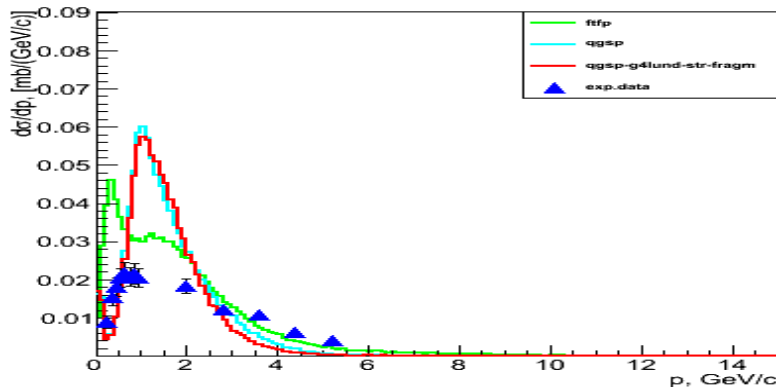
proton + C \rightarrow X + proton (100 < theta < 140 (mrad))



proton + C \rightarrow X + proton (140 < theta < 180 (mrad))

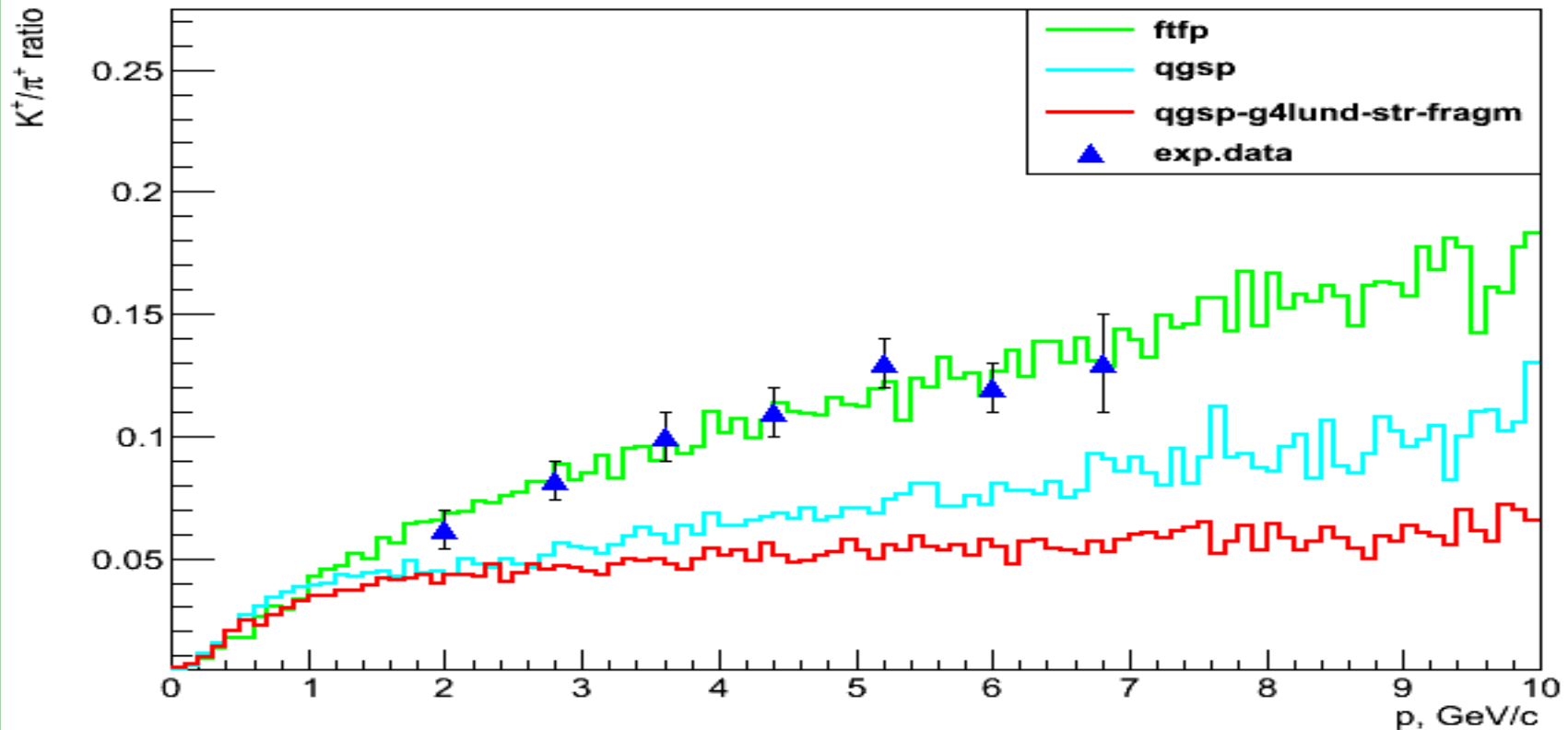


proton + C \rightarrow X + proton (180 < theta < 240 (mrad))



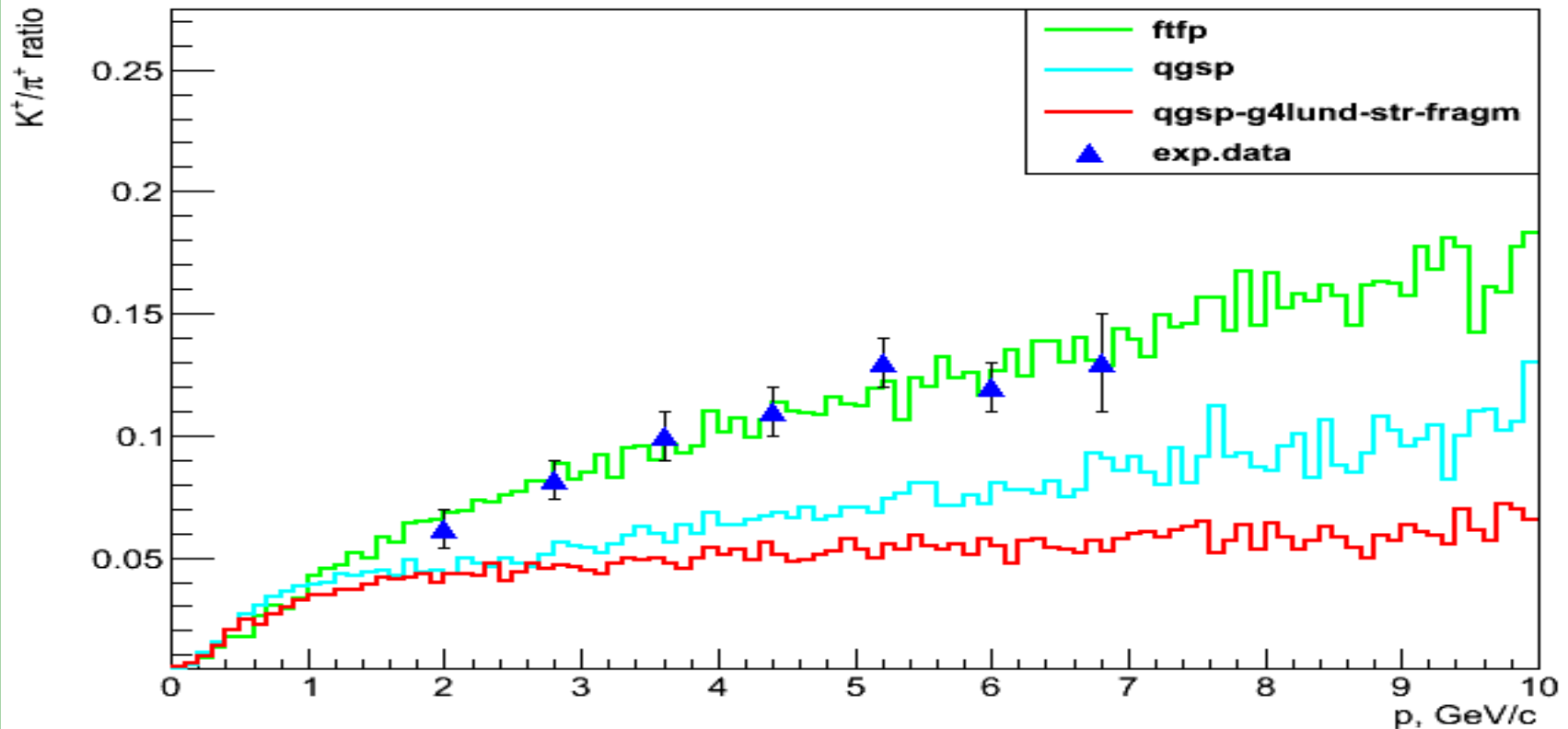
NA61: 31 GeV/c proton on C K⁺/π⁺

proton + C, K⁺/π⁺ (20<theta<140 (mrad))



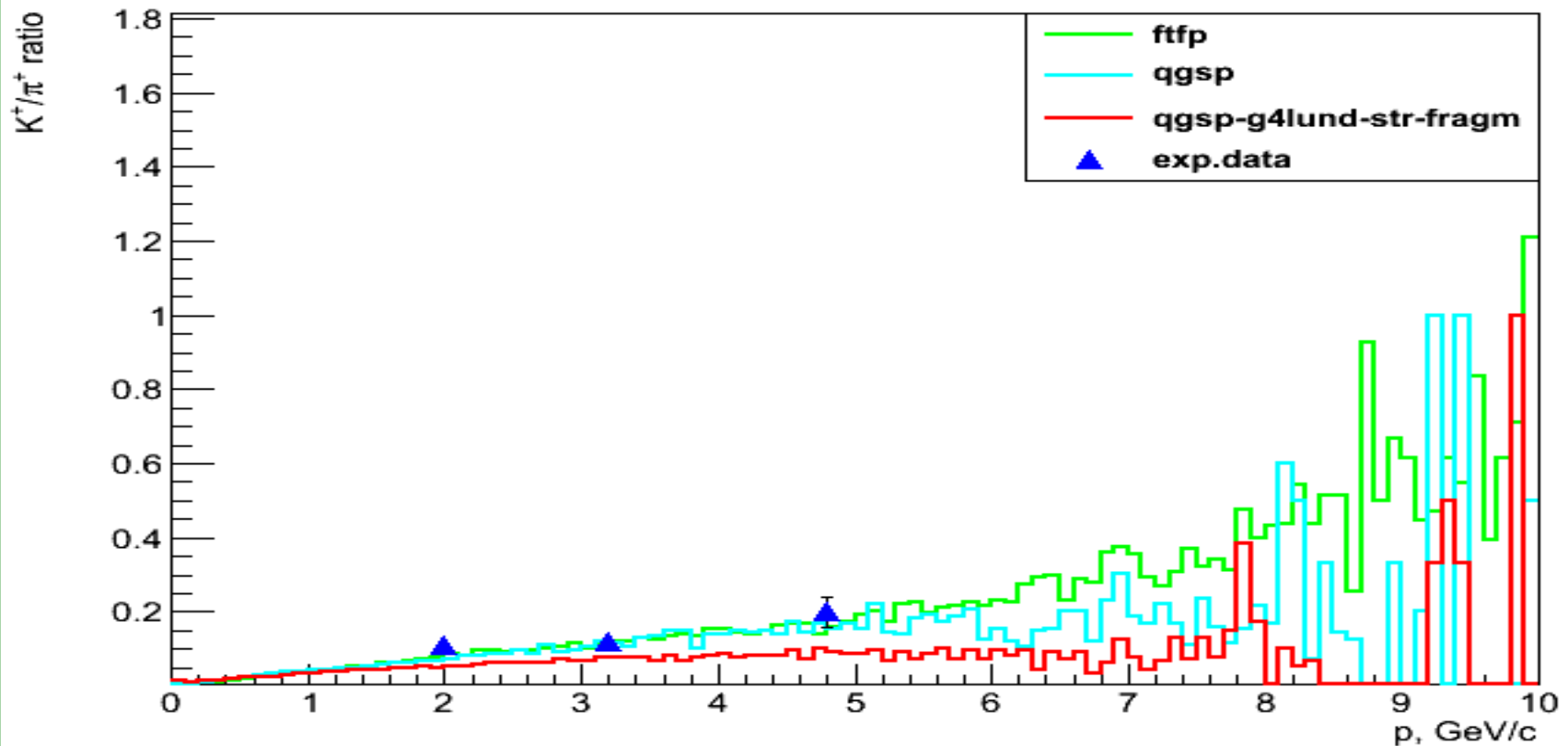
NA61: 31 GeV/c proton on C K⁺/π⁺

proton + C, K⁺/π⁺ (20<theta<140 (mrad))



NA61: 31 GeV/c proton on C K⁺/pi⁺ (cont.)

proton + C, K⁺/pi⁺ (140<theta<240 (mrad))





Summary (I)

- Geant4 offers 2 options for modeling HE hadronic interactions: FTF-based or QGS-based
- Each model calls for several other components (quasi-elastic, string fragmentation, intra-nuclear transport...) - some have been worked on recently, some have remained untouched
- Some of these components are “interchangeable”
- Model is per particle type, in a given E-range
- Standard physics lists include particular combination of these, but it can be customized



Summary (II)

- FTF(P) is current and has been worked on recently; in its standard configuration it appears to be reasonable in the several tens GeV range
- QGS(P) is older and remained untouched in the recent past; however, it shows a good fit with the p+C data at higher energies ($>100\text{GeV}$?), especially with the newer string fragmentation
- Work is in progress
- Feedback is welcome, to trigger improvements

Just FYI: large collection of Geant4 hadronic validation materials is available:

<http://g4validation.fnal.gov:8080/G4ValidationWebApp/G4ValHAD.jsp>

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http://g4v...ValHAD.jsp

g4validation.fnal.gov:8080/G4ValidationWebApp/G4ValHAD.jsp

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Geant 4

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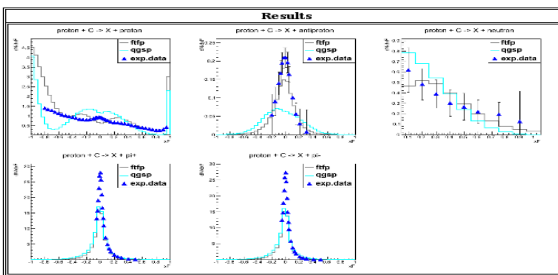
Home Validation Overview Release Highlights Electromagnetic Hadronic LHC-feedback Expert

Name of the Test: test19
Responsible: J. Yarba (Fermilab)
Description: high energy test, provides comparison with NA61 (31GeV/c proton beam) and NA49 (158GeV/c proton beam) data sets.

Geant4 Version: geant4-9.6-p01
Observable: average density of p, pbar, n, pi+, or pi- as a function of xF
Reaction: p on C
Status: public

Test Conditions	
Name	test19
last-modified	2013-02-21 16:13:55 CST
Target	Carbon
Energy	158 GeV/c
Particle	proton
Comment	Both FTF and QGS models are backed with PreCompound model
Model	FTF(P), QGS(P)
Reference	NA61, Phys. Rev. C84, 034604 (2011)
Reference	see further details
Score:	passed
Type:	expert

Results



List of hadronic Tests

- Hadr1on
- HadrXS
- HadrCap
- IAEA
- Ndata
- Testfragm
- placeholder
- simplifiedCalo
- test19
- p on C
- geant4-9.6-ref03
- test22
- test30
- test35
- test45
- test47
- test48
- test75

Julia Yarba - O... yarba_j@cluck:/... [7.2. User Inter... yarba_j@cluck:... [Yahoo! - Mozill... Mozilla Firefox Starting Take Sc...